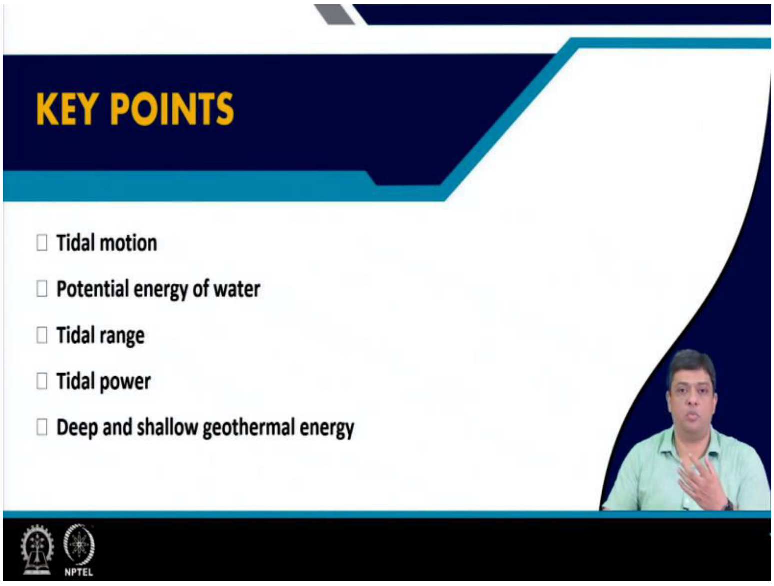
Physics of Renewable Energy Systems
Professor. Amreesh Chandra
Department of Physics
Indian Institute of Technology Kharagpur
Lecture 19
Tidal Power and Geothermal Energy

Welcome, today we will be finishing the modules on energy generation technologies, which we plan to discuss in this course on Physics of Renewable Energy Systems and from next lecture onwards, we will be moving towards the energy storage technologies and the necessity for having energy storage technologies. So, let us finish today the remaining part on of tidal power and then also discuss briefly the geothermal energy.

(Refer Slide Time: 01:07)

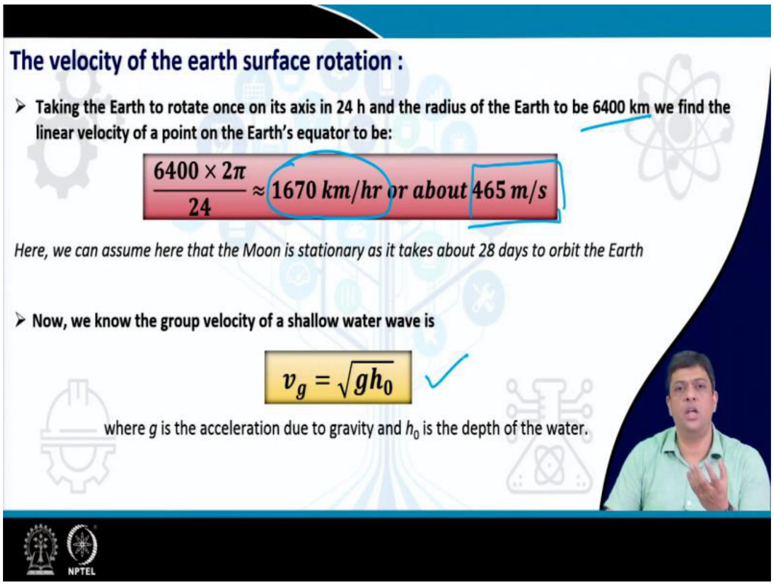
Hence, the concepts covered in today's lecture would be mainly two, the first one would be harnessing tidal power and second would be the introduction to geothermal energy, which is also being proposed as a novel way to extract renewable based energy.

(Refer Slide Time: 01:39)



The key points of today's lecture would be quick revision of tidal motion, potential energy of water which is flowing and has height because of the flow of this tide. Then you will talk about what is tidal range, extraction of tidal power and finally, we will spend some 10, 15 minutes on giving you a brief introduction towards deep and shallow geothermal energy.

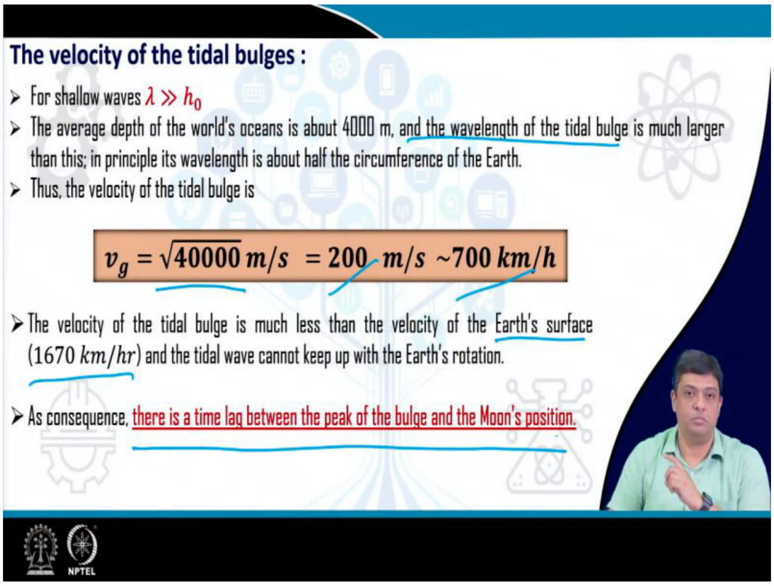
(Refer Slide Time: 02:22)



Let us revise, what is the velocity of a point on Earth's surface, taking the Earth's surface or the rotation of the Earth of around its access to be 24 hour and the radius of the earth to be approximately 6400 kilometres we can calculate that the linear velocity of a point on the Earth's equator would be approximately what, would be 1670 kilometres per hour or that turns out to be 465 metres per second.

Here, we can thus assume that Moon is stationary as it takes about 28 days to orbit the Earth. Let us consider the case of shallow water wave. In the previous discussions, when we were talking about deep water and shallow water, I hope you remember which regions you consider as shallow regions or and which regions you consider the appearance of deep waterways. So, knowing the group velocity of a shallow water wave is given by what, is equal to under root g into h_0, where h_0 is the depth of the water and g is the acceleration due to gravity.

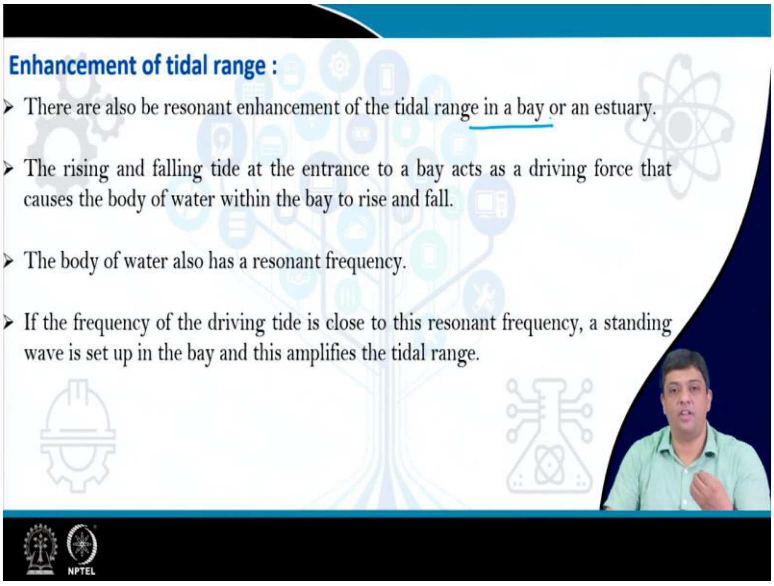
(Refer Slide Time: 04:08)



For shallow waves, lambda is much greater than h_0. What happens, we have just considered that the average depth of the world's ocean is approximately 4000 metres and the wavelength of the tidal bulge is much larger than this and in principle, its wavelength is about half the circumference of the earth. Thus, the velocity of the tidal bulge is given as 40,000 under root metre by second that turns out to be around 200 metres per second or 700 kilometres per hour.

Compare with what, the rotation of the Earth value was given, the velocity of the tidal bulge is much less than the velocity of the Earth surface, which is rotating and the value for the case when we were considering Earth's surface what, 1670 kilometres per hour. Hence, that tidal wave cannot keep up with the Earth's rotation. What is the immediate consequence? The immediate consequence is, there is a time lag between the peak of the bulge and the Moons position.

(Refer Slide Time: 05:43)

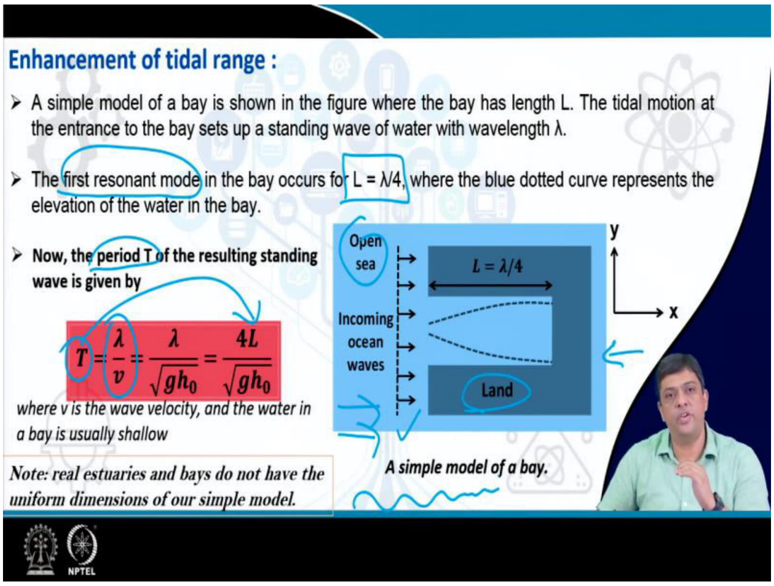


Now, there are also a resonant, resonant between what, resonant which can happen due to the interaction of this water or entry of this water in a bay or estuary, where the flowing river is meeting the sea or you are having water entering a nanochannel in the land. So, this can result in appearance of tides and if you set up some kind of stationary waves, then you can also have the appearance of resonance, this will become clear in the next slide.

Now, you have obtained the condition where you are seeing the tides. The rising and falling of these tides at the entrance of the bay acts as the driving force, driving force for what, that causes the body of the water within the bay to rise and fall. So, now you have tides and this is making it to rise and fall this force.

Now, you have a small channel, you have kept some water in this. The body of water also has a resonant frequency. Therefore, if the frequency of the driving time is close to the resonant frequency, a standing wave is set up in the bay and once you have a standing wave, what happens the tidal range is even enhanced further or you can say that the tidal range is amplified.

(Refer Slide Time: 07:58)

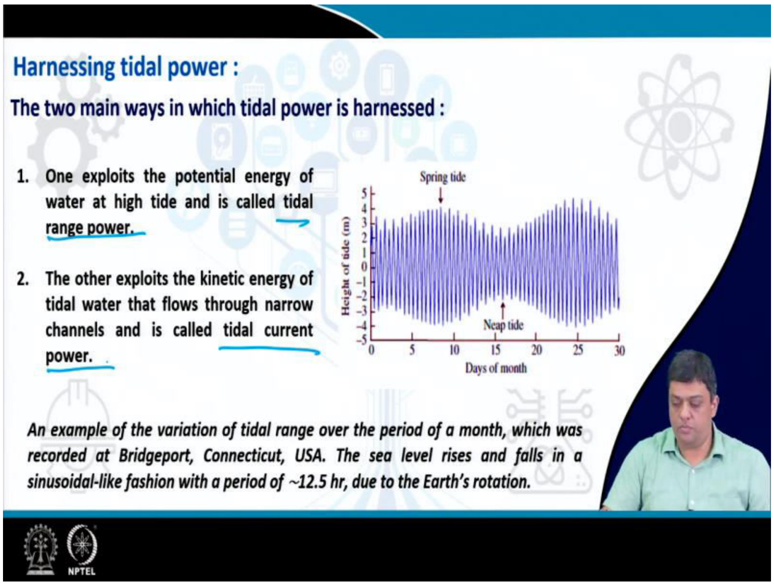


This is what we are talking about in words let us explain it more in detail. So, what happens you have the open sea and incoming waves, these waves they are entering the bay that is a small channel, that the place where the incoming ocean waves are entering the land area. But tidal motion at the entrance of the bay sets up a standing wave of water with wave length lambda. What will be the first resonant mode? This would occur and the condition where L is equal to lambda by 4.

And here the blue dotted curve represents the elevation of the water in the bay. Now, what you have done, you have obtained a condition where you are setting up the standing waves. This will result in the calculation of the time period T. This is given by lambda by v, where v is the wave velocity and the water in the bay is usually considered to be shallow and hence, T is equal to 4 L by and root g h_0. We are taking the value of v g in shallow region.

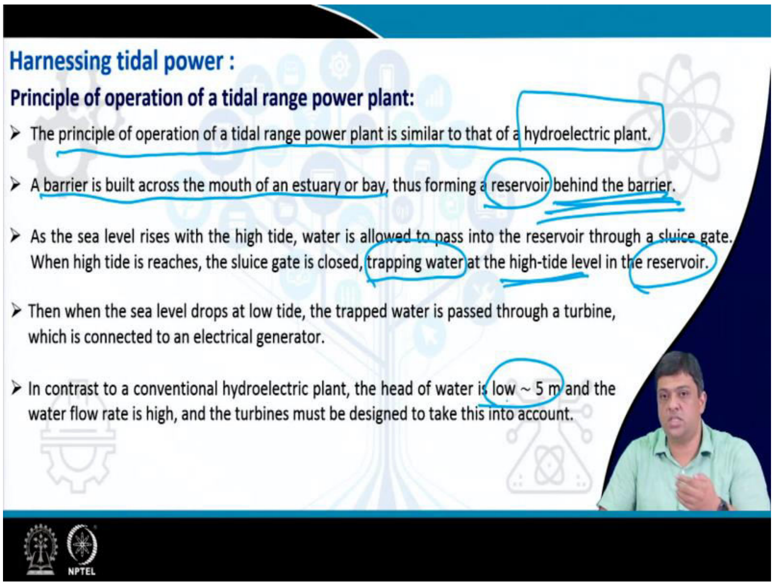
Please note, in real estuary and bay, this is not the example or smooth figure which you can take, because these are not uniform, as if the way we have drawn here, you can have the land structure which is non-uniform. So, the values may be slightly different, because you have the surface which is not as ideal as the one which has been considered in the figure. But to start this is a very simple model which gives you the indication and the rough values which you will obtain.

(Refer Slide Time: 10:50)



As we discussed in the previous lecture. There are two ways of extracting tidal power one is tidal range power, what do we do there, we exploit the potential energy of the water at high tide and the second is what, it is the tidal current power where we considered the flow of the tidal one and examples are already available, where such concepts have been used.

(Refer Slide Time: 11:27)



What is the principle of operation of tidal range power plant, what are you going to use? I hope now, the answer will be very clear or you will be able to give an answer in a very short time that you have a flowing water you have also the variation in the waves, if I can install certain technology which can extract this power you have the tidal range power. So, we are indicating towards the use of turbines, let us say water turbines in this case.

Therefore, the principle of operation of tidal power plant is similar to that of hydroelectric plant. What do we do in hydroelectric plant? We have a reservoir. So, in comparison to this, if you are asked to develop a tidal range power plant, what will you do? You will build a barrier across the mouth of the bay thus forming a reservoir behind a barrier, behind the barrier.

So, similar to hydroelectric plant, you are generating or creating a reservoir. As the sea level rises with the high tide, water is allowed to pass into the reservoir through the sluice gates. And if you are able to close these sluice gates, then what will happen, you will find the water is trapped and they are trapped at high tide levels, they are trapped where, in the reservoir.

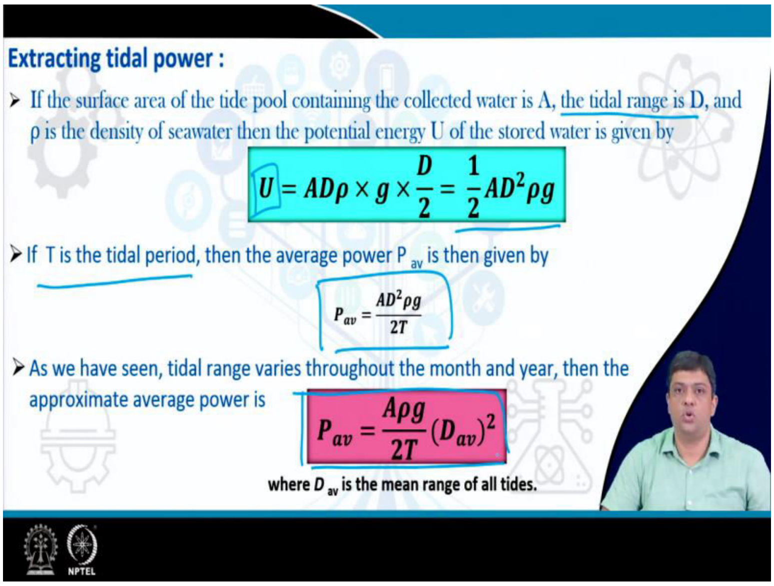
So, you have high tide water flows, you open the gates, let the water go in water maintains the same level, close the gate. Now, you have the water at the same tide level, but now they are in the reservoir. Then when the sea level now drops at the low tide that trap water is passed through the turbine, which is connected to an electrical generator.

So, automatically you have constructed a height difference and when the water is allowed to go back to the ocean, when the tides recite, then you can use this conversion of potential energy flowing down. That means conversion from potential to kinetic energy running of the turbines and then flowing back into the ocean.

So, in this case, in contrast to conventional hydroelectric plants where you had a reservoir, then you were talking about the head and then flowing water downwards through the penstock here, the head of the water is low, there you are talking about few ten hundreds of metres, here the head of the water is approximately 5 metre or so.

Along with that, the flow of the water is high and therefore, what should be done, because you have low head height, then the turbines must be so designed that they can use the flow rate more effectively than they were critical in the hydroelectric plants. So, that is what you must remember, because the head you are talking about in the tidal range power plants are much lower than what you talked about a hydroelectric plant, but the situation is similar.

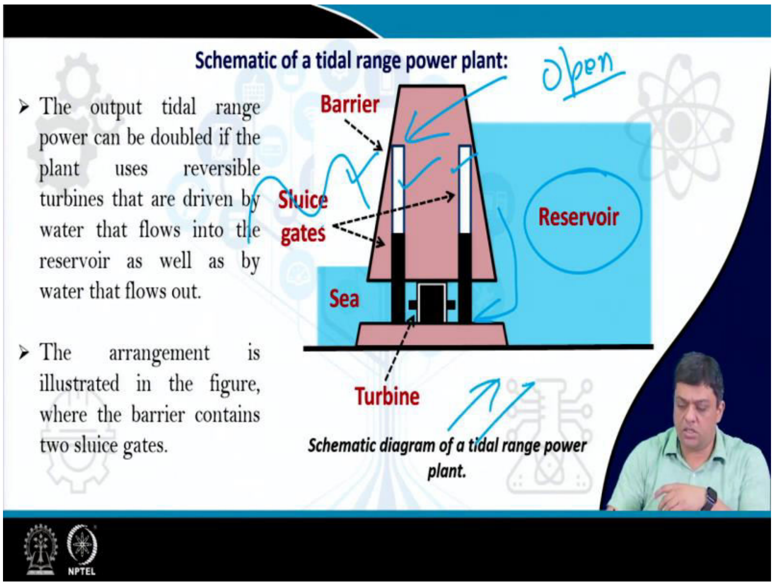
(Refer Slide Time: 16:05)



So, if the surface of the tide pool containing the water is A. Let us say the tidal range is D and rho is a density of a seawater. What would be the potential energy that you will obtain for a stored water? That would be U equal to half A D square rho g. If T is a tidal period, then the average power would be obtained as P average equal to A D square rho g by 2 T. Because at each point what happens, you have in a 24-hour period, you have the high tides being generated twice.

As we have seen the tidal range varies throughout the month and year, then the approximate average power is given by not taking the value as D for the tidal range, but taking an average value which is the mean range of all tides. So, you get the average power equals to P average equals to A rho g by 2 T into D average whole square.

(Refer Slide Time: 17:34)

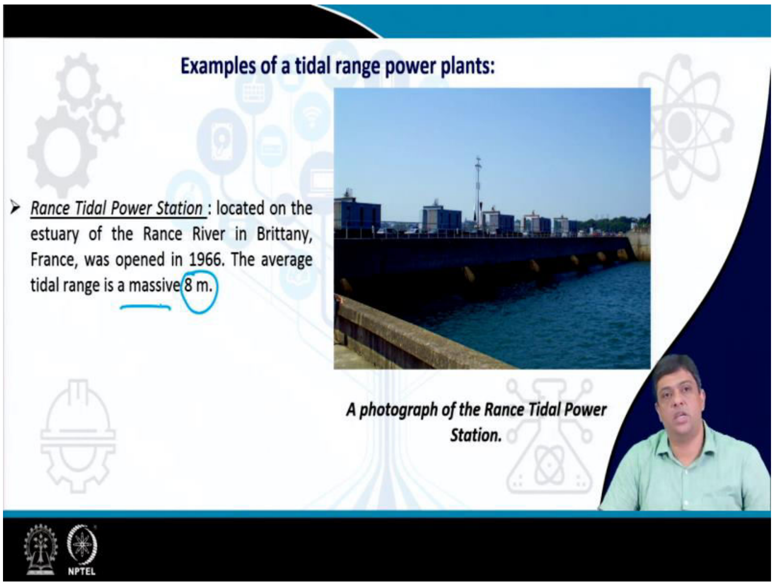


This is a typical schematic of a tidal range power plant. What do you have? You have the sluice gates, you have the barrier when the, in the high tides, when the tides are high you will open these sluice gates, then the water will be filled in the reservoir, when the condition of low tides are obtained, you will have the condition of water flowing down through the turbines and back into the sea or ocean.

Very simple design, operation is simple, similar to what we have discussed earlier, you just have to remember the fact that the output tidal range power can be doubled if the plant uses a reversible turbine that are driven by water that flows into the river's reservoir and as well as what, when they have the condition of the water is flowing back.

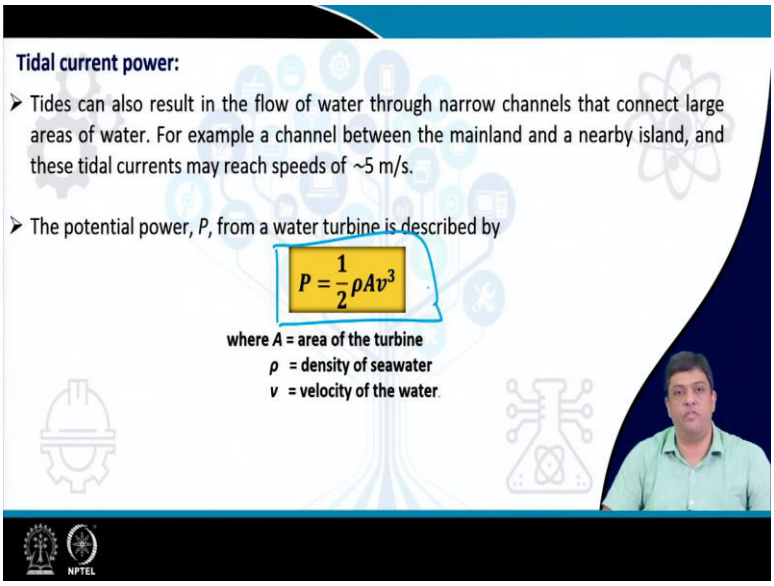
Do you remember what was the design when we were talking about air, vibrating air column water converters, the wells turbine. So, similar to wells turbine, if you can have the turbines in tidal range power plants, then the output can be enhanced and this is what we just discussed.

(Refer Slide Time: 19:26)



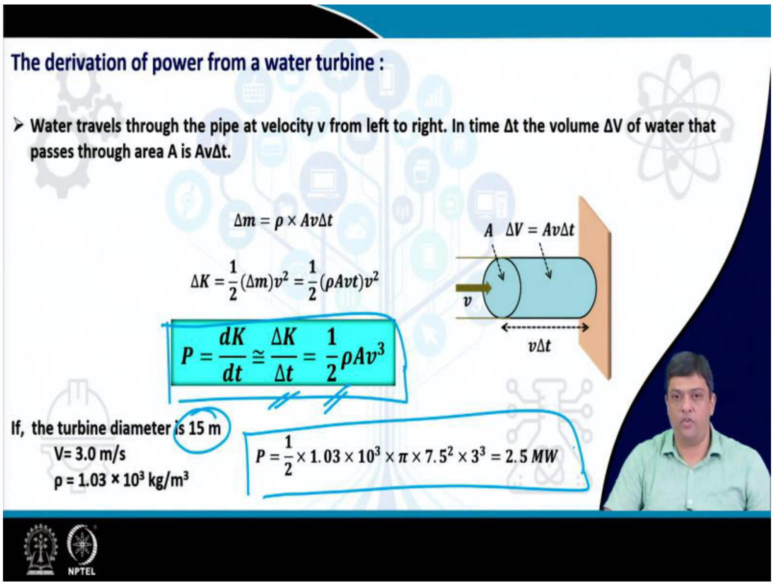
This is an example of an installed tidal range power plant in France and here the average tidal range is 8 metres and 8 metres is not a small range. It is a massive range, you are talking about, you are talking about 8 metre high tides.

(Refer Slide Time: 19:50)



The second strategy which was there to extract the tidal power was using the kinetic energy of the flowing tides and you had tidal current power. So, as we saw in the earlier case, the potential power P from a water turbine is described by P is equal to half rho A v cube, where A is the area of the turbine, rho is the density of the sea water and v is the velocity of the power.

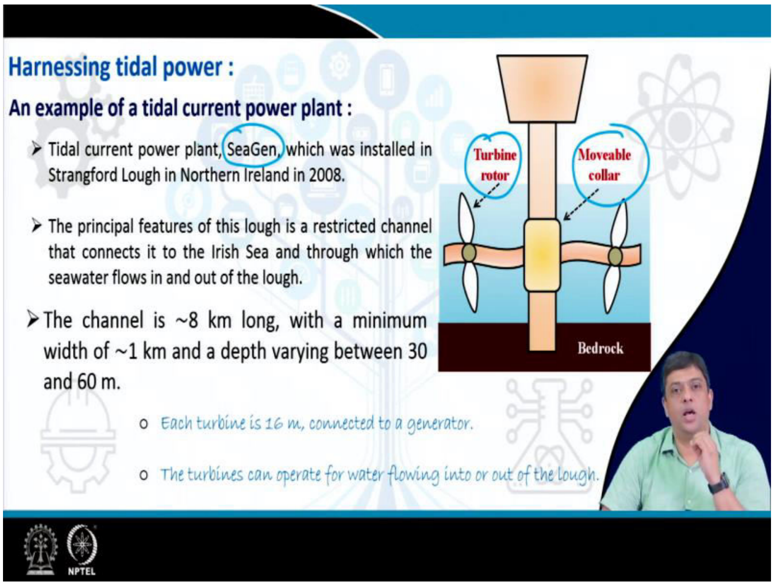
(Refer Slide Time: 20:29)



And we come back to our famous example, which we have been discussing in many lectures that you have flowing fluid hitting the wall and then transferring energy to the wall and then if you can extract this power. So, using the similar conditions, you will find that the power which you will have in this case would be given as delta K by delta T, that is equal to half rho A v cube.

And if you make a simple calculation and keep things to be ideal, let us say you have a turbine which has a diameter of 15 metres, the value of v is 3 metres per second and the density of water which you are considering is 1.03 into 10 to the power 3 kg per metre cube, then you can extract nearly 2.5 megawatt. So, although it looks to be very simple, but when we consider the amount of power that can be extracted that is quite high and therefore, the strategy is quite useful in various places.

(Refer Slide Time: 21:58)

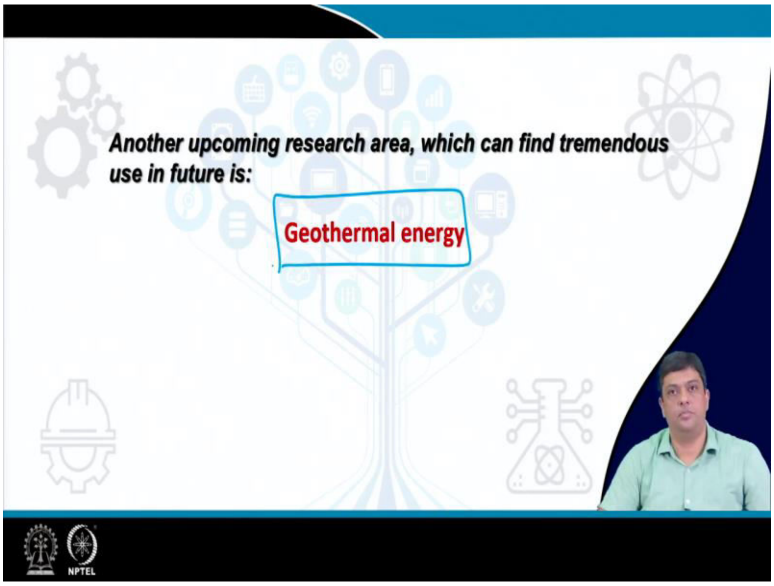


And this is a typical example or design of a tidal current plant, you have the turbine motors you have the movable collars and what you can do is you can either lift this whole turbine out of the water if you do not want the power to be generated or you can let the turbines be sent back in the water. So, you can lower the turbine inside the water, you can extract it out of the water.

So, you can have both these concepts, so when you need the electricity generation, you will lower the turbine inside in the water and if you do not want it, you will take it out of the water and this is rest of the working remains the same which we discussed in the previous slides.

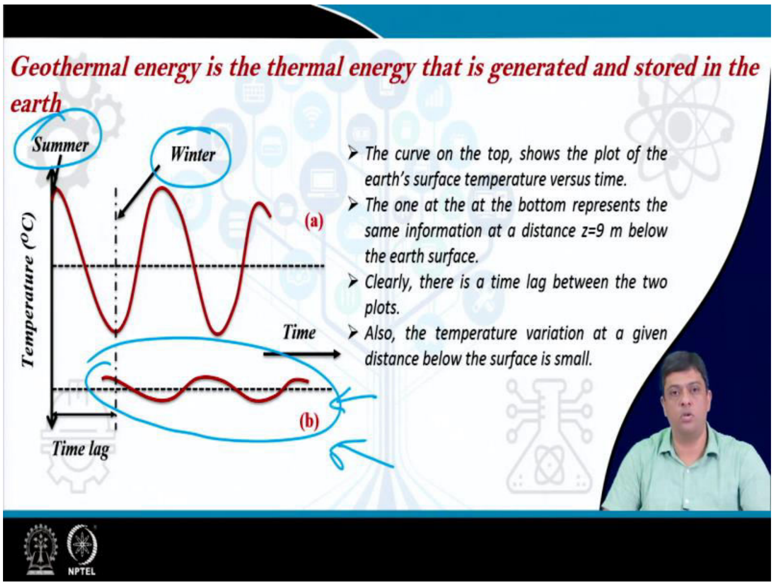
Here, if you take example like which has been installed in Northern Ireland, which is called as SeaGen, each turbine is approximately 16 metres, which are connected to generator and they can operate for water flowing into or out of the area very, similar to the Wells turbine. So, you see that tidal power also has tremendous application and can become a promising technology for the future.

(Refer Slide Time: 23:40)



Let us now, very quickly give you a brief introduction to another topic, which is being discussed and proposed by many researchers and that is geothermal energy.

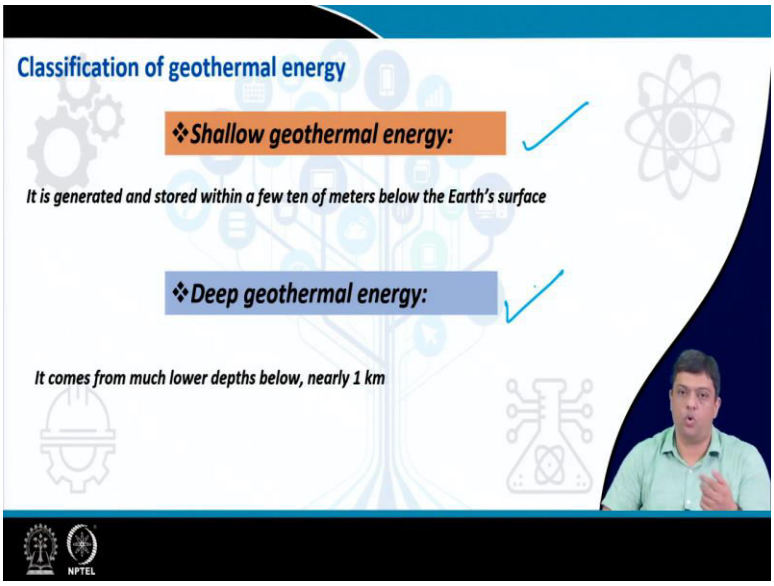
(Refer Slide Time: 24:05)



What is geothermal energy? Geothermal energy is the thermal energy that is generated and stored in earth. So, as you go down the earth, you see the temperature increases and if that increases, if you can extract that heat, then maybe you can have the condition where you can use that heat.

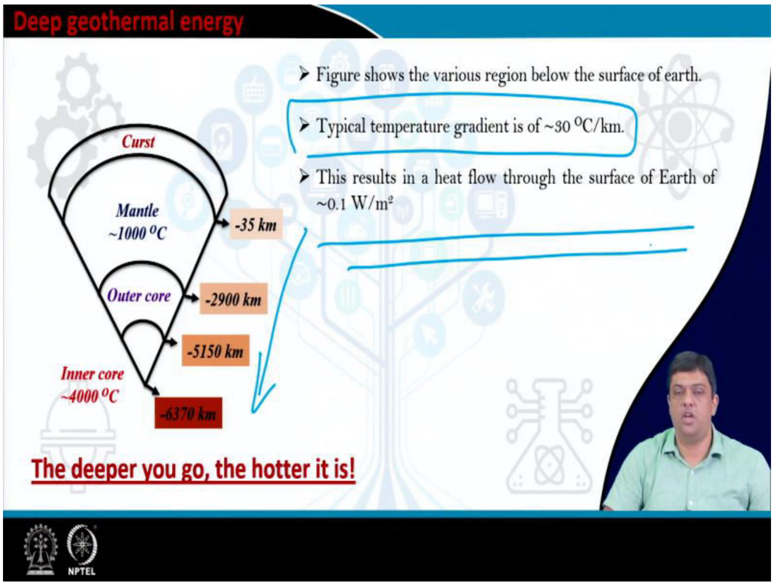
And typically, if you see on the surface of the earth, you will find that the temperatures changes as a function of time and it happens both during summers or winter in a day. But if you draw the corresponding curve below the earth surface and if as low as let us say 10 metres plus minus, then you see that the difference in the temperature is much more suppressed. So, the temperature at the, at various levels below the surface of the Earth is nearly the same and as you go down the temperature increases.

(Refer Slide Time: 25:33)



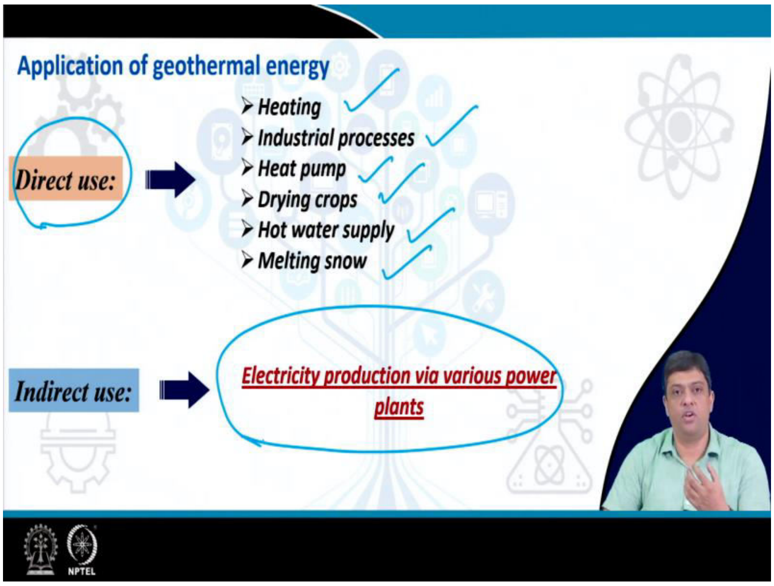
And, there are strategies proposed to extract this energy or the heat which is there below the surface and therefore, you have two types of geothermal energy. The first one is shallow geothermal energy and the second is deep geothermal energy. The shallow geothermal energy are the ones which are generated and stored within few 10s of metres below the Earth's surface, when but when we talk about deep geothermal energy, we are talking about the energy which comes from much lower depths, let us say 1 kilometre or more.

(Refer Slide Time: 26:28)



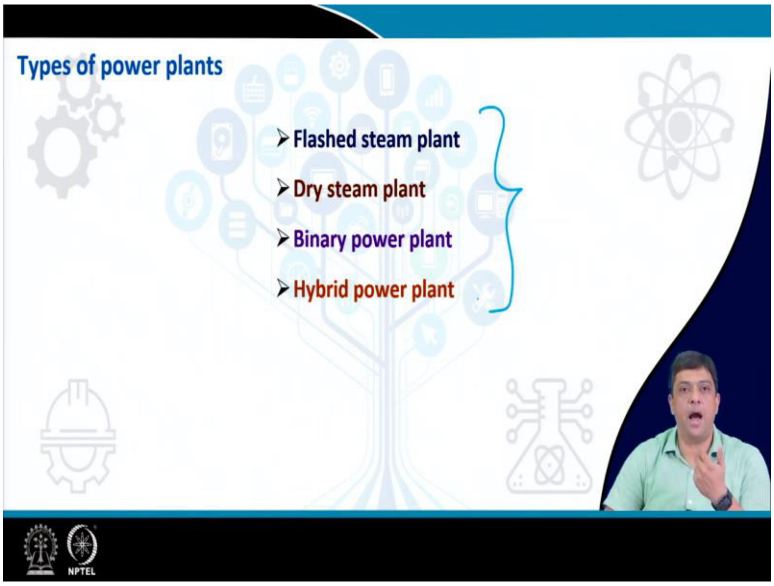
This is a typical example, if you see as you go below the Earth's surface, then the temperature increases, the deeper you go the hotter it is and the typical gradient is 30 degrees per kilometre. So, if I go 1 kilometre below the surface, you will find that the temperature is increased by 30 degrees or so and this results in our heat flow through the surface of the Earth at a rate of 0.1 watt per metre square.

(Refer Slide Time: 27:09)



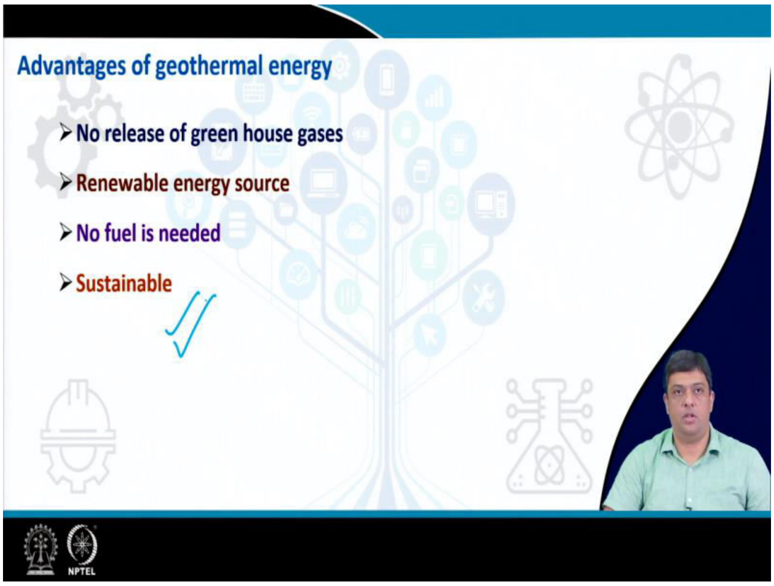
So, if I can extract this energy, then you can use this form of energy for direct use, if I have taken that heat out, then I can straightaway use for heating, different industrial processes, heat pump, drying of crops or heating of water which can be used or hot water supply or melting of snow. Indirect could be electricity generation using various kinds of plants and that is probably going to be exploited in times to come as we move more towards a renewable based energy landscape. So, I thought to give you a brief introduction about this technology.

(Refer Slide Time: 28:07)



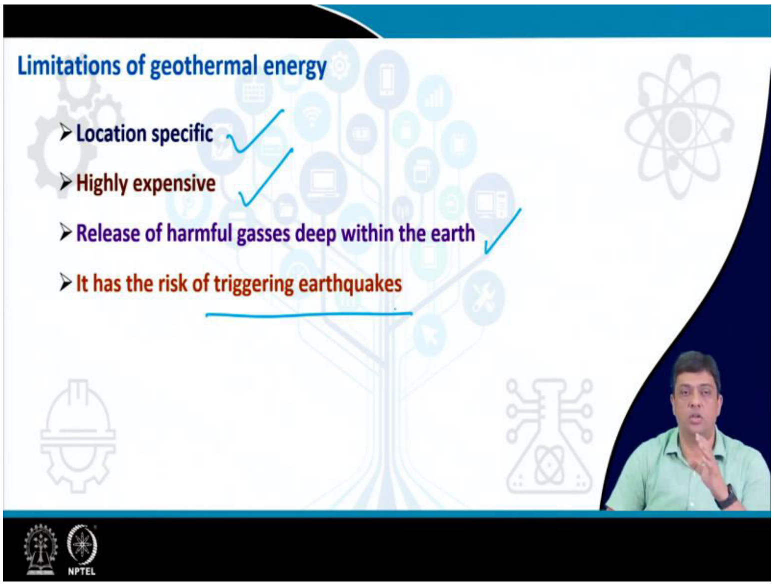
There are already various types of power plants, which are being proposed. They are classified as flashed steam plant, dry steam plant, binary power plant or hybrid power plants.

(Refer Slide Time: 28:31)



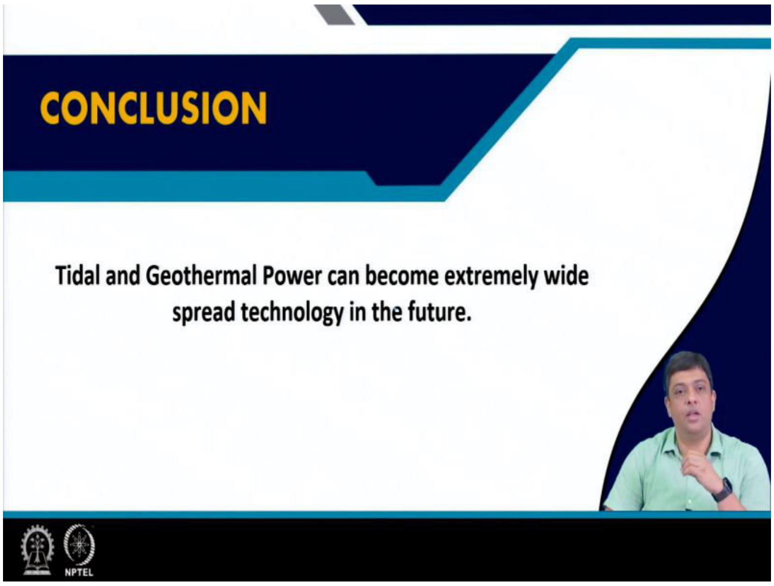
And these plants, which are based on geothermal energy are associated with certain advantages and disadvantages as expected. The main advantages are that they are mostly not associated with release of any greenhouse gases. They are using a renewable source, there is no need for additional fuel and the whole technology is quite sustainable.

(Refer Slide Time: 29:12)



But the disadvantages are also quite a few and they need to be countered before this technology finds large scale use. The limitations are it is location specific, as of today is very expensive. And because you have release of harmful gases deep within the earth, you can have various other products which can come out when you are extracting the heat and if you are having drills or you are installing these power plants, you have the risk of triggering earthquakes. So, there are various limiting factors on this technology, but you must know that it is being proposed and investigated by many researchers for use in the future.

(Refer Slide Time: 30:25)



So, I hope it is clear to you that tidal and geothermal power can become extremely widespread technology in the future as of today, for a country like India, we are mostly focusing on solar and wind and we have already been using hydroelectric plants. But as we invest more funds, as we promote research in these areas, you will find that plants which are based on tidal and geothermal energy would become visible at various places in our country.

(Refer Slide Time: 31:19)

This is the major reference from which the data was collected and with this lecture, I finish the topics where we have focused on energy generation systems. From next lecture, we will be talking about the need for energy storage technologies and then we will talk about the various types of storage technologies that are useful for our country. Thank you very much for attending this lecture and have a nice day.